

Arkwood, Inc., Superfund Site

EPA Comments on Draft Supplemental Groundwater Tracing Summary Report dated March 2015

McKesson Corporation Response-To-Comments

Item No.	Reference	EPA Comments Dated October 9, 2015	PRP Response
	Supplemental Groundwater Tracing Summary Report General	<p>The maps and figures used to identify the site and important sampling locations can be improved.</p> <p>Generation of water-level maps (water table and potentiometric) would help with identifying pathways. All receptors (other adjacent withdrawal wells) should be identified on maps.</p>	<p>The map/figure in the report has been improved to better identify the site and sampling stations in the <i>Revised Supplemental Groundwater Tracing Summary Report</i>.</p> <p>Generation of “water-level maps (water table and potentiometric)” is beyond the scope of the Supplemental Groundwater Tracing Study. This task was not identified in the EPA-reviewed and subsequently revised work plan (Aley 2014). Since water levels were not measured in any groundwater monitoring wells or public or private water supply wells as part of the tracer study, such information was not included in the <i>Supplemental Groundwater Tracing Summary Report</i>.</p> <p>Eleven dye monitoring points (identified as “A” through “K”) were referenced incorrectly as “wells” in the summary report. These locations are actually cased soil borings in a tight grouping in the former sinkhole area. These borings were installed following the sinkhole remediation as injection points for ozone treated water during the groundwater remedial effort in the mid 2000s. Although cased with PVC pipe, these soil borings are not constructed to monitoring well standards. They do not have sand packs, well seals, or protective well completions. For the most part, they are constructed only to the top of bedrock in non-native material used as clean backfill following the sinkhole remediation. They have not been surveyed. A more accurate and complete description of these soil boring locations, including the details contained in this Response-to-Comments, is provided in the <i>Revised Supplemental Groundwater Tracing Summary Report</i>.</p> <p>Most of the soil borings (A through K) are connected to a below ground piping network that supplied ozone treated water to the former sinkhole area during a portion of the groundwater remediation history from approximately 2005 through 2009 and non-ozonated water from approximately 2010 through 2012. During the Supplemental Groundwater Tracing Study, this below ground piping was used to deliver clean water (not treated by ozone) from the on-site deep well pair to the former sinkhole area to flush the dyes from the soil borings into the subsurface following the dye introductions.</p> <p>Although water levels were measured in the cased soil borings on several occasions, most of the borings were dry. Due to the age of the former treatment system (including the cased soil borings), some of the valve seals leak water into the borings when closed. In the winter when the tracing study was performed, water was circulated in the piping to prevent freezing. Because of this circulation of water and the age of the system, several of the borings had a small amount of water in a consistent stream flowing into them through the leaking seals. Most of the locations that did contain measurable water</p>

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			<p>levels also had water leaking into them from the water piping system. As such, the measured water levels are artificial in nature and do not represent actual groundwater conditions.</p> <p>In addition, the Remedial Investigation (RI) Report (ERM 1990) does not identify adjacent withdrawal wells as “<i>receptors</i>”. Wells within a 1.5-mile radius of the site are identified in the RI report as well as a discussion of the well search (Figure 3-3 and text pages 3-3 and 3-6). In Section 5 Pathway Analysis, the RI report states “...<i>springs and domestic wells sampled in the area during the RI have not shown any detectable traces of Arkwood indicator constituents.</i>” (Page 5-1).</p> <p>Furthermore, as identified in the Superfund Record of Decision (ROD) for the site (USEPA 1990) and supported by an extensive collection and analysis of data in the Remedial Investigation (ERM 1990), the evaluation of well data does not provide an accurate depiction of subsurface groundwater conditions due to the karst topography of the area. Approaches useful for a homogeneous aquifer are not appropriate for this site where there is enormous heterogeneity of conditions. The “<i>Declaration</i>” (introductory) section of the ROD states: “<i>the area is underlain by karst geology which prevents the use of monitoring wells as a method of predicting contaminant movement...</i>”</p>
2.	Supplemental Groundwater Tracing Summary Report General	Less than 50% of the dye was recovered/detected at sample locations. It is speculative to assume that an equivalent amount of dye or greater was retained in non-mobile volume of the rock. Another scenario is that all pathways were not determined and some deep underflow occurs.	<p>Dye Recovery Percentages: Low total mass of dye recoveries is routine when dye tracing in real world applications. The recovery percentages at New Cricket Spring are very high when compared with tracing in similar subsurface conditions. The following case studies are provided as supporting evidence:</p> <ul style="list-style-type: none"> • Three recently conducted groundwater traces by the Ozark Underground Laboratory, Inc. (OUL) in the Boone Formation in Benton County, Arkansas (same units as those at the Site) resulted in the detection of 15.0%, 2.7%, and 5.75% of the introduced dye. (Beeman and Aley 2015) • A dye trace to Dyers Spring, Kentucky through a cave stream resulted in the detection of 62.5% of the introduced dye. (Smoot et al. 1987) • Four traces at a CERCLA site in karst near Frederick, Maryland over distances of less than a mile resulted in the detection of 0.9%; 0.2%; 0.1%, and 0.01% of the introduced dyes over a 9 month sampling period. (White et al. 2015) • Dye recovery percentages were calculated for an extensive groundwater tracing program in the Barton Springs segment of the Edwards Aquifer, Texas. Based on 20 groundwater traces for straight-line distances ranging from 2 to almost 19 miles, the tracer recoveries ranged from almost 0% to 77% of the mass of dye introduced. The mean recovery was about 16% and the median recovery percent was about 4.2%. In the executive summary, the authors reported that the amount of tracer recovered did not vary directly with distance. However, larger amounts of dye were routinely used for longer distance traces. (Hauwert et al. 2004) <p>No reports of deep seepage that might have accounted for low dye recovery percentages were included in any of these references. Additional data and discussion is included in the <i>Revised Supplemental Groundwater Tracing Summary Report</i>.</p>

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			<p>Dye Attenuation and Loss within the Aquifer: Dye that was not recovered during the 7-week Supplemental Groundwater Tracing Study can be attributed to the following processes:</p> <ul style="list-style-type: none"> • Diffusion and dispersion into immobile porosity, whether it be: <ul style="list-style-type: none"> ○ “Dead-end” pore spaces in the saturated zone, or ○ Only seasonally saturated pockets in the epikarst that were flooded during the dye and flush water introduction that stranded some of the dye mass when water levels dropped following the addition of the flush water. • Sorption processes (including adsorption, chemisorption, and absorption) and partitioning onto immobile aquifer surfaces as the dyes moved through the subsurface; • Biodegradation and oxidation within the aquifer which would account for a reduction in dye mass; • Some dye remained in the dye introduction and adjacent borings in the former sinkhole area, as demonstrated by the results of activated carbon samplers from those locations, even after large volumes of water were used to flush the dye from the vicinity of dye introduction borings. • Small amounts of dye continued to discharge after the sampling program ended as minor amounts of dye desorbed from aquifer materials and diffused back into the mobile porosity. <p>The tracer dyes can be viewed as a surrogate for the contaminants at the site. Obviously, the tracer dyes have different properties (water soluble as opposed to relatively insoluble constituents) and exhibit different fate and transport characteristics. However, as the contaminants continue to discharge at New Cricket Spring after more than 30 years since contaminants were introduced into the subsurface and 20 years since source area remediation was initiated, some of the dye is also tied up in the subsurface and continues to discharge beyond the sampling duration.</p> <p>Supporting data contradicting the possibility for “deep underflow” and alternate discharge locations:</p> <p>A comprehensive dye tracing study was performed in 1991-92 (Aley 1992). Groundwater data and related information also was collected for, and reported in, the RI (ERM 1990), which evaluated the potential for “deep underflow.”</p> <p>A major groundwater tracing study was conducted at the Site in 1991. Two traces, each involving the introduction of 10 pounds of fluorescein mixture and 28.5 pounds of rhodamine WT mixture, were introduced into the groundwater system to on each end of known impact to effectively bracket the Site. A total of 83 sampling stations were used during this tracing work, including two private wells, one on-Site monitoring well, and the on-Site deep well. No dye was detected at any of these wells.</p> <p>The results of the 1991 study indicated dye introduced in the southeast area of the site (Trace 91-01) discharged in the Railroad Tunnel Spring and in sampling stations downgradient of the railroad tunnel in the Walnut Creek topographic basin. The results of the 1991 dye introduction downstream of New</p>

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			<p>Cricket Spring (Trace 91-02) discharged in four zones downgradient of New Cricket Spring in the Cricket Creek topographic basin. It is important to note that this second dye introduction in 1991 was in the Cricket Spring Branch downgradient of New Cricket Spring and not from the Site.</p> <p>Water yielded from the spring in the railroad tunnel discharges from the southeastern end of the tunnel and into the Walnut Creek Valley. The recent <i>Supplemental Groundwater Tracing Study</i> sampled all water discharging from New Cricket Spring and all water discharging from the southeastern end of the railroad tunnel. The entire railroad tunnel, which is about 2,657 feet long, slopes to the southeastern mouth of the tunnel and is lower in elevation than the dye introduction points for the two dye introductions made in 2014. The tunnel is thus positioned to intercept groundwater from beneath the site.</p> <p>Based upon the results of the comprehensive groundwater tracing study in 1991, the sampling stations monitored as part of the more limited Supplemental Groundwater Tracing Study in 2014 were appropriate in consideration of the dye introduction locations and the amount of dyes used.</p> <p>During the 1991 tracing program, conducted during the winter and spring months, precipitation at the Site was approximately equal to the long-term mean. A major seven-day storm occurred from April 11 to 18, 1991 during the study period, when 5.07 inches of precipitation was recorded at the Site. Although not during the dye introduction, this rainfall event clearly resulted in high flow conditions during the tracing period.</p> <p>The Remedial Investigation included the collection of numerous lines of evidence to evaluate the potential for deep seepage and alternative discharge locations of contaminated groundwater from the Site.</p> <ul style="list-style-type: none"> • Well search in a 1.5 mile radius of the Site, including an agency record search and interview of area citizens. Subsequent sampling of representative wells. • Spring reconnaissance within 1.5 mile radius of the Site and subsequent sampling of representative locations. • Both shallow and deeper borings, some of which were converted to wells. However it was determined that the wells did not create a viable monitoring network in the karst subsurface environment and were subsequently abandoned. <p>Representative locations of each type were sampled for site indicator constituents of concern. In addition, geochemical profiling was performed to compare deeper and shallow groundwater. No evidence for deep underflow was documented in the RI.</p> <p>The ROD states “<i>there appears to be no connection between the shallow karst aquifer and deeper water supply aquifers</i>” (page 9) and further states “<i>a shallow unit (the Sylamore Sandstone) appears to act as</i></p>

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			<p><i>an aquiclude restricting downward migration of the shallow groundwater in the vicinity of the site</i>" (page 11).</p> <p>Additional discussion is provided in the <i>Revised Supplemental Groundwater Tracing Summary Report</i>.</p>
3.	Supplemental Groundwater Tracing Summary Report Section 1.3 Hydrogeologic Setting Page 4.	<p>The report states, "<i>The semi-quantitative dye tracing investigation discussed in this report provides a valuable on-Site measurement of the percent of mobile porosity existing in the most impacted portion of the shallow epikarstic zone aquifer at the Arkwood Site.</i>"</p> <p>The report does not provide the procedures used to estimate the percent mobile porosity based on the results of the tracer tests. The report should be revised to include this information.</p>	<p>The percentage of dye detected during the sampling period (45% for fluorescein and 38% for rhodamine WT) is a measure of the amount of dye that was transported to New Cricket Spring through the mobile porosity within the portion of the aquifer affected by historic discharges into the former sinkhole. The percentages are not specifically a measure of mobile porosity, but rather provide an estimate of mobile porosity since much of the dye that was not discharged was diffused into the immobile porosity or subject to sorption processes onto immobile aquifer materials. Given the highly heterogeneous nature of the aquifer, these values are more relevant to contaminant transport from the former sinkhole area to New Cricket Spring than are mobile porosity values calculated from measurements made over aquifer distances of a few feet.</p> <p>The <i>Revised Supplemental Groundwater Tracing Summary Report</i> has been changed to remove the discussion of mobile porosity within the aquifer since this was not one of the original objectives of the study.</p>
4.	Supplemental Groundwater Tracing Summary Report Section 1.4 Previous Groundwater Tracing Study	<p>The report states that one trace was introduced at the "woodchip pile" at the southeast corner of the site, and that "<i>The 1991 tracing demonstrated that the Site was underlain by a groundwater divide. Groundwater from the southeastern portion of the Site discharges to the Walnut Creek topographic basin and groundwater from the northwestern portion of the Site discharges to the Cricket Creek topographic basin.</i>"</p> <p>This is an important aspect of the tracer study, and it relates</p>	<p>Although we agree with EPA's acknowledgement that the data support the existence of a groundwater divide at the site, we disagree with EPA's conclusion that the groundwater divide moves significantly enough under high flow conditions to include discharge from the former sinkhole area into the Walnut Creek topographic basin. No data support the idea of appreciable movement of the groundwater divide associated with high flow events. It is important to recognize that during the 1991 groundwater tracing study at the Site no dye introduced at the southeast corner of the Site discharged from New Cricket Spring or in any location in the Cricket Creek topographic basin.</p> <p>The results of the <i>2014-15 Supplemental Groundwater Tracing Study</i> demonstrated that flow from the former sinkhole area does not discharge into the Walnut Creek topographic basin under the flow conditions tested. The proposed high flow tracer study will further evaluate the potential for discharge from the former sinkhole area into the Walnut Creek topographic basin, as well as to various identified seeps and springs in the Cricket Creek topographic basin (in addition to New Cricket Spring) under high flow conditions.</p> <p>The presence of a groundwater divide at the site does not necessitate the conclusion that site contaminants discharge into the Walnut Creek topographic basin or that New Cricket Spring does not</p>

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		<p>to the overall feasibility of the New Cricket Spring to fully capture contaminated ground water at the Arkwood site.</p> <p>Multiple lines of evidence are consistent with a ground water flow divide hydrologic conceptual model. Therefore, the on-site multi-directional contaminated ground water flow directions, particularly at high spring discharge rates (i.e., “peak flows”) are unlikely to be captured by the New Cricket Spring located off-site on the west side of the facility. Given this preliminary assessment of the data and information, it appears unlikely that capture of all the contaminated ground water by New Cricket Spring has been attained.</p> <p>It would be worthwhile to re-evaluate the ability of the New Cricket Spring ground water treatment system to fully capture all of the contaminated ground water emanating from the area encompassed by the Arkwood site.</p>	<p>capture all contaminants presently being discharged from the Site. As detailed in the RI, contaminants were not uniformly distributed across the Site. The southeast area of the Site was impacted by contaminants in impacted soils. Bedrock and groundwater were not determined to be impacted in the area. A comprehensive soil remediation was completed in that area followed by the installation of a soil cap. This area is not a continuing source of groundwater impact, as demonstrated by previous contaminant sampling performed in the Walnut Creek topographic basin following the 1991-92 tracer study.</p> <p>Although we agree the groundwater divide can shift to some extent based on subsurface groundwater levels in the epikarst, there is no evidence that suggests the divide moves far enough northwest to include the former sinkhole area where liquid wastes were disposed during Site operations. If this were the case, contaminant sampling in the Walnut Creek topographic basin in the 1990s and since would have produced evidence of contaminant impact.</p>
5.	Supplemental Groundwater Tracing Summary Report Section 2.2.1	The report states, “ <i>Composite water samples were collected to permit a mass balance calculation for each tracer dye. This information permits a measurement of the percent</i>	<p>This comment is the same issue addressed in Comment 3.</p> <p>The <i>Revised Supplemental Groundwater Tracing Summary Report</i> has been revised according to the discussion provided in the response to Comment 3. The discussion and conclusions relating to mobile porosity have been removed from the revised report.</p>

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	Types of Samples Page 8	<i>of mobile porosity in the portion of the epikarstic aquifer lying between the former sinkhole and New Cricket Spring.</i> The report should specify what calculations were used to estimate “mobile porosity.”	
6.	Supplemental Groundwater Tracing Summary Report Table 5 Page 9	Please label the injection wells.	This revision is included in the <i>Revised Supplemental Groundwater Tracing Summary Report</i> . The injection points are actually soil boring holes rather than wells. The revised report refers to them as borings.
7.	Supplemental Groundwater Tracing Summary Report Figure 1 Page 10	City water location #18 is missing on the map. Please label the springs.	These revisions are included in the <i>Revised Supplemental Groundwater Tracing Summary Report</i> .
8.	Supplemental Groundwater Tracing Summary Report Section 2.3 Laboratory Analyses Page 12 Appendix A Page A-7	The report states, “Activated carbon samples were rinsed under a relatively strong jet of water, eluted in a standard eluting solution. Water samples were pH adjusted to raise the pH of the water to 9.5 or higher.” Appendix A indicates the elution solution is typically comprised of an alcohol, water, and a strong basic solution such as aqueous ammonia and/or potassium hydroxide. Information should be provided regarding the	Section 3.3.2 Mass Balance Calculations (page 19) of the summary report states, “The mass of dye discharging from New Cricket Spring was calculated from the composite water samples and flow rate measurements.” The mass balance was based on water samples, not data from activated carbon samplers. The use of a strongly basic solution to elute dye from activated carbon samples is the state-of-the-art procedure for dye tracing lab analysis (Weight 2008; Benson and Yukr 2015). The report is revised to include these references. Data generated from the activated carbon samplers was not used for the mass balance calculations since more precise data from composite water samples were also generated during the study for the specific purpose of calculating a mass balance.

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		extent to which a mass balance could be achieved in the complete removal of the dyes from the carbon as a control sample.	
9.	Supplemental Groundwater Tracing Summary Report Table 8 Page 15	A runoff rate per area would be helpful to assess whether underflow is occurring at the weir.	Regarding Table 8 (Precipitation and Flow Rate Measurements) on pages 12-13: Since the area of New Cricket Spring has not been conclusively delineated, a runoff rate per area would be difficult to accurately calculate. Runoff rate calculations are based on estimates of a number of factors and resulting values often depart widely from actual conditions. Runoff rate calculations are simply not sensitive enough, or accurate enough, to detect small amounts of “underflow” if it, in fact, exists. Furthermore, careful field examination has found no evidence of flow passing beneath the weir.
10.	Supplemental Groundwater Tracing Summary Report Tables 9 through 11 Pages 16 through 19	Including travel times in the table would be helpful.	Important travel times are included in Table 16 on page 20 in the discussion of the mass balance calculations. In the <i>Revised Supplemental Groundwater Tracing Summary Report</i> , additional discussion regarding travel times is included in the sections requested.
11.	Supplemental Groundwater Tracing Summary Report Section 3.3.2 Mass Balance Calculations Page 22 Second paragraph	<p>The report states, “<i>The technical literature suggests that dye traces from sinkholes to springs are typically characterized by 20 to 50% of the introduced dye being detected at the receiving spring (Aley 1997). The detection percentages from this study are within the reported range.</i>”</p> <p>The potential array of possible testing conditions that could occur for a specific tracer test is broad and dependent on many site variables. Therefore, it does</p>	<p>The statement from the summary report quoted in the comment is correct. The text of the report has been revised to include information provided in our response to Comment 2 with the associated literature citations. These data demonstrate the wide range and generally low amount of dye mass recoveries. The report does not claim that the percent recoveries during the supplemental tracing of 45% for fluorescein and 38% for rhodamine WT are a quality assurance or quality control metric.</p> <p>.</p>

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		<p>not seem prudent that the range of recovery reported (20-50%) should serve as a quality assurance or quality control metric.</p> <p>An analysis to quantify the immobile porosity should be provided to support this point, if this point is to be considered valid.</p>	
12.	Supplemental Groundwater Tracing Summary Report Section 3.3.2 Mass Balance Calculations Page 22 Third paragraph	<p>The report states, “<i>The detection percents for the two dye traces (45% for fluorescein and 38% for rhodamine WT) provide a measure of mobile porosity in the most contaminated portion of the groundwater system at the Arkwood Site.</i>”</p> <p>Please clarify how the mobile porosity was calculated from the dye tracer test results.</p>	<p>This comment contains the same issue as addressed in Comments 3 and 5.</p> <p>The <i>Revised Supplemental Groundwater Tracing Summary Report</i> has been revised according to the discussion provided in the Response to Comment 3. The discussion and conclusions relating to mobile porosity have been removed from the revised report.</p>
13.	Supplemental Groundwater Tracing Summary Report Section 3.3.2 Mass Balance Calculations Page 22 Third paragraph	<p>The report indicates the dye that was not recovered was detained within the non-mobile portion of the epikarstic aquifer. An additional tracer fate mechanism that was not investigated or discussed involves the transport of the tracer beyond the capture zone of the New Cricket Spring.</p> <p>Specifically, under this condition the tracers would bypass the capture zone of the spring. Please clarify why it was inferred that the</p>	<p>Please see response to Comment 2. An extensive regional tracing study to identify groundwater discharge from the Site was conducted following the RI (Aley 1991). A tracer study under high flow conditions is planned for early 2016 and is expected to further support the conclusions in the <i>Supplemental Groundwater Tracing Summary Report</i>.</p>

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		unrecovered dye did not simply bypass the New Cricket Spring.	
14.	Supplemental Groundwater Tracing Summary Report Section 3.3.2 Mass Balance Calculations Page 22	The report seems to conclude that all pathways have been identified and, therefore, the amount of dye recovered is a function of mobile and immobile porosity, but this is not stated or supported.	<p>The design of the <i>2014-15 Supplemental Groundwater Tracing Study</i> was based upon the results of the Remedial Investigation (ERM 1990), as reflected in the ROD (USEPA 1990) and the <i>1991-92 Groundwater Tracing Investigation</i> (Aley 1992).</p> <p>As discussed in the Response to Comment 2, multiple lines of evidence supported by data generated by the RI and the comprehensive groundwater tracing study conducted in 1991 indicate no deep underflow or alternative discharge locations warranting additional sampling locations during the Supplemental Groundwater Tracing Investigation.</p> <p>The amount of dye recovered is reasonable when compared to groundwater tracing results at other sites in the same geologic formation and elsewhere. Evidence from the RI and previous groundwater tracing do not suggest other discharge locations. However, an additional tracing study to be conducted under high flow conditions is being developed and will provide a more comprehensive sampling protocol to address EPA concerns.</p>
15.	Supplemental Groundwater Tracing Summary Report Section 4 Summary and Conclusions Item 1 Page 24	The report states that “ <i>groundwater from the former sinkhole area on-Site only discharges from New Cricket Spring.</i> ” The evidence from the tracer study does support the idea that the majority of groundwater is discharged from New Cricket Spring; however, low levels of dye were detected in Cricket Pond which indicates that some groundwater is following other pathways. Therefore, the absolute of New Cricket Spring being the only discharge point is not supported. The evidence does support the statement that, at	<p>New Cricket Spring supplies water to Cricket Pond. Small amounts of dye passed through the treatment system and were discharged into the ditch along Cricket Road and ultimately flowed into Cricket Pond. Visual dye was seen flowing on the surface and through culverts from the New Cricket Spring treatment plant to Cricket Pond. Additional discussion and photographs are provided in the revised report (see photos in Appendix D). Based upon the visual dye seen discharging from the New Cricket Spring treatment plant, the concentrations of dye detected in the Cricket Pond discharge, and the detection limit being much lower than the visual threshold, the concentrations of both fluorescein and rhodamine WT dyes detected in the Cricket Pond discharge are interpreted to be dye that was first discharged from New Cricket Spring. No dye was directly discharged from the groundwater system to Cricket Pond.</p> <p>Additional data will be collected during the proposed high flow groundwater tracer study to further address this conclusion and EPA’s concerns.</p>

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		low flow levels, a majority of the groundwater from the former sinkhole discharges from New Cricket Spring.	
16.	Supplemental Groundwater Tracing Summary Report Section 4 Summary and Conclusions Item 1 Page 24	<p>One of the conclusions from the study is presented as: “1. Groundwater from the former sinkhole area on-site only discharges from New Cricket Spring. Groundwater from this area does not discharge from [Old] Cricket Spring, the southeast end of the railroad tunnel, or in the Walnut Creek valley.”</p> <p>This conclusion is based on:</p> <ul style="list-style-type: none"> • the mean flow discharge rates from New Cricket Spring recorded during the study period from November 1, 2014, to January 5, 2015, • detection of dye in New Cricket Spring, and • the lack of dye discharge from [Old] Cricket Spring. <p>However, more than 55 percent of the dye mass was unaccounted. The mass of dye unaccounted was attributed to immobile porosity, but no analysis of the immobile porosity attribution was presented.</p> <p>The immobile porosity hypothesis is therefore unsubstantiated, and it is not</p>	<p>Regarding EPA’s Comment: “<i>The study did not have adequate monitoring points to evaluate dye flow paths in the subsurface; rather, samples were collected at known points of spring discharge.</i>”</p> <p>We strongly disagree. The study did have adequate monitoring points to evaluate dye flow paths based upon the results of the 1991 comprehensive tracer study.</p> <p>A previous regional scale groundwater tracing study was conducted at the Site during the winter and spring of 1991. It included a total of 83 sampling stations and the introduction of two dyes at two separate dye introduction points that bracketed the Site. The total mass of dye mixtures introduced for these previous traces was 77 pounds. Sampling stations included wells, springs, surface stream segments selected to identify any springs that might have discharged into the channels of the streams, and points in both the Cricket Creek and Long Creek Arms of Table Rock Lake. The results of the 1991 study indicated dye introduced in the southeast area of the site (Trace 91-01) discharged in the Railroad Tunnel Spring and in sampling stations downgradient of the railroad tunnel in the Walnut Creek topographic basin. The results of the 1991 dye introduction downstream of New Cricket Spring (Trace 91-02) discharged in four zones downgradient of New Cricket Spring in the Cricket Creek topographic basin.</p> <p>Water yielded from the spring in the railroad tunnel discharges from the southeastern end of the tunnel and into the Walnut Creek Valley. The recent <i>Supplemental Groundwater Tracing Study</i> sampled all water discharging from New Cricket Spring and all water discharging from the southeastern end of the railroad tunnel. The entire railroad tunnel, which is about 2,657 feet long, slopes to the southeastern mouth of the tunnel and is lower in elevation than the dye introduction points for the two dye introductions made in 2014. The tunnel is thus positioned to intercept groundwater from beneath the site. In addition, during the 2014 tracing work Old Cricket Spring (tributary to Cricket Creek and downstream of New Cricket Spring) was sampled and Walnut Creek Valley Spring and Walnut Creek North (both of these stations at elevations below the southeast mouth of the railroad tunnel) were also sampled. No dyes were detected at any of these sampling locations.</p> <p>EPA reviewed the work plan for the study and did not raise any objection that the sampling points were inadequate.</p> <p>Regarding EPA’s comment: “<i>A contaminated groundwater capture analysis is needed for the site that provides quantitative evidence that the contaminated ground water leaving the site is captured by New</i></p>

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		<p>known if bypass flow is occurring at elevations lower than the discharge point of New Cricket Spring, or if there is discharge to depth beneath the former sinkhole. The study did not have adequate monitoring points to evaluate dye flow paths in the subsurface; rather, samples were collected at known points of spring discharge.</p> <p>Overall, the dye study and previous ground water monitoring data provide evidence that New Cricket Spring captures limited amounts of contaminated ground water leaving the Arkwood Superfund site. It is possible that contaminated ground water is bypassing New Cricket Spring both laterally and beneath the artesian spring. A contaminated ground water capture analysis is needed for the site that provides quantitative evidence that the contaminated ground water leaving the site is captured by New Cricket Spring, or else there should be another way of demonstrating where the contamination is going.</p> <p>At a certain (unknown) threshold water level in the epikarst formation (and</p>	<p><i>Cricket Spring, or else there should be another way of demonstrating where the contamination is going."</i></p> <p>The results from the 1991 groundwater tracing program, enhanced by results from the 2014 Supplemental Groundwater Tracing and which will be further enhanced by the planned tracing work under high flow conditions provides a clear method of demonstrating where any residual contamination is going. Water discharging from New Cricket Spring is collected and treated.</p> <p>The railroad tunnel spring is located about 800 feet from the southeastern end of the tunnel. This is an active railroad tunnel currently used by multiple trains on the typical day. The spring can be sampled for tracer dyes by sampling the tunnel drainage at the southeastern end of the tunnel. This is not a credible approach for sampling contaminants of concern due to the presence of treated railroad ties and other materials and compounds related to railroad activities in the tunnel. During the RI, only New Cricket Spring and one sample from the railroad tunnel spring detected organic contaminants from the site. The one detection from the railroad tunnel spring (0.061 mg/L PCP) was below the EPA water quality criterion of 1.01 mg/L. This sample was collected before remedial activities occurred at the site. No other previous or subsequent samples from this spring indicated the presence of wood treating compounds. No other springs in the study area were found to contain wood treating compounds during the RI. None of the domestic or municipal drinking water wells were shown to be affected.</p> <p>A detailed evaluation of off-Site groundwater discharge was performed during the RI/FS process and recorded in the ROD. No additional data have been generated to suggest that additional discharge locations exist.</p> <p>A high flow tracer study work plan is being developed to address the concerns of the EPA. It will be submitted under separate cover.</p>

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		<p>consequential high flow rate from New Cricket Spring), the mobile porosity will exceed the elevation of the groundwater divide on the site, with potential contaminant discharge to the adjacent railroad tunnel spring, as has previously occurred.</p> <p>Additional investigative activities should be completed to account for this issue.</p> <p>It would be very useful to conduct a dye test in concert with peak discharge colloidal sampling event to evaluate whether or not there is bypass groundwater flow or discharge to depth in the Karst system. The testing and sampling should include subsurface monitoring points (i.e., wells) to evaluate if flow is bypassing New Cricket Spring or there is vertical discharge to deeper parts of the karst system.</p>	
17.	Supplemental Groundwater Tracing Summary Report	<p>The report indicates the fate of the dye is either: (1) that it was captured by the New Cricket Spring; or, (2) that it was “detained in the non-mobile porosity of the epikarstic aquifer.” Dye transport into immobile pores could take months and years. But in this case, the tracer test lasted 7 weeks and peaked at the New</p>	<p>Regarding EPA’s Comment: <i>“Dye transport into immobile pores could take months or years. But in this case the tracer test lasted 7 weeks and peaked at the New Cricket Spring within 8-16 hours of injection allowing limited time for diffusive transport.”</i></p> <p>The Supplemental Tracer Study Work Plan (page 7) states: <i>“We anticipate that most of the dye that discharges from New Cricket Spring will pass through the spring within 7 weeks of the time of dye introduction. In the event that sample analysis after the first 4 weeks of sampling indicates that the duration of a major portion of the dye pulse is likely to last longer than seven weeks, we will recommend that the study be extended for one or more three-week sampling cycles.”</i> The purpose of the supplemental dye trace (as stated in the work plan) was to provide data about water movement from that portion of the Site most heavily impacted by PCP and associated dioxins to the primary point where</p>

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		<p>Cricket Spring within 8-16 hours of injection allowing limited time for diffusive transport. No data or information was provided to suggest that the unrecovered dye could have bypassed the New Cricket Spring. It appears that the hydrologic conceptual model suggested in this report is that all the ground water associated with the western portion of the site, and possibly all of the ground water underlying the site, is captured by the New Cricket Spring. This does not seem to be justified.</p> <p>Based on the physical properties of PCP (density, solubility in water, and increased water solubility with increased pH in karst terrain), it appears that a large volume of this contaminant may be stored within the epikarstic aquifer, and it would be likely to be discharged in response to fluctuating groundwater levels indefinitely.</p> <p>The detections of low levels of introduced dyes in Cricket Pond indicate that other pathways from the sinkhole area are possible.</p> <p>Due to various lines of evidence, a direct conduit between the sinkhole and the</p>	<p>contaminated groundwater discharges to the surface. Sampling with composite water samples at New Cricket Spring lasted for 49 days. Concentrations of both fluorescein and rhodamine WT dyes at New Cricket Spring decreased by over 3 orders of magnitude during the course of the study. The supplemental tracer test fully complied with the work plan that EPA reviewed.</p> <p>Regarding EPA's Comment: <i>"It appears that the hydrologic conceptual model suggested in this report is that all the ground water associated with the western portion of the site, and possibly all of the groundwater underlying the site, is captured by the New Cricket Spring. This does not seem to be justified."</i> For clarification please see Figure 2 in the revised <i>Supplemental Dye Tracing Summary Report</i>. The sinkhole area is best described as being in the northwestern part of the Site, not the western portion. Wood treating was conducted around the sinkhole and the nearby building. Treated and untreated wood was stored elsewhere on the Site and drippage from the treated wood contaminated underlying soils. The contaminated soils have been removed and replaced with a cover of top soil. The OUL conclusion, supported by data from the Supplemental Tracer Study, is that all detected dye from the sinkhole area dye introductions discharged from New Cricket Spring. The Supplemental Tracer Study was conducted under moderate groundwater flow conditions. No dye from that trace was detected at sampling stations monitoring the railroad tunnel or at Old Cricket Spring. Another tracer study to be conducted during winter/spring 2016 will assess water flow from the sinkhole area under high flow conditions. Among other sampling points, the planned new trace will sample any seeps found around New Cricket Spring, the railroad tunnel, and nearby areas.</p> <p>Regarding EPA's Comment: <i>"The detections of low levels of introduced dye in Cricket Pond indicate that other pathways from the sinkhole area are possible."</i> Cricket Pond receives water from New Cricket Spring that has passed through the treatment system. Especially during peak discharge, small concentrations of dye passed through the treatment system. Cricket Pond also receives water from Old Cricket Spring. Old Cricket Spring was sampled independently and neither of the tracer dyes was detected in that spring.</p> <p>On November 18, 2014 (the day following the dye introductions), visible dye was seen discharging from New Cricket Spring, discharging from the treatment plant, and in all other locations of surface flow downstream of the New Cricket Spring treatment plant and upstream of Cricket pond. A more detailed discussion of the visible dye seen in surface flow between New Cricket Spring and Cricket Pond, as well as the series of photos taken on the morning of November 18, 2014, are included in the Revised Supplemental Tracing Study Report (specifically Appendix D).</p> <p>Regarding EPA's Comment: <i>"It would be informative to inject tracer dye where other waste management activities and/or former process areas were located, and not just the sinkhole area."</i> This is what was accomplished by the 1991 tracer study when dyes were introduced at the southeast margin</p>

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		<p>New Cricket Spring has been established. At the outset of the tracer test, it was unclear whether the spring would fully capture the entire mass of tracer injected into the sinkhole area. Based on the results of these tracer tests, it does not appear prudent to conclude that the New Cricket Spring captures all the contaminated ground water passing from the sinkhole area. It would be informative to inject tracer dye where other waste management activities and/or former process areas were located, not just the sinkhole area. As it is, conclusions are not possible regarding the extent to which New Cricket Spring captures contaminated ground water passing through other areas of the site.</p> <p>A more extensive investigation should be planned to consider what happens when the flow rates are significantly higher than those tested in this study. Potential high-flow discharge points (e.g., New Cricket Spring and the railroad tunnel discharge) should be sampled and tested for both tracer dye and for dioxin concentration in groundwater.</p>	<p>of the site and into the discharge from New Cricket Spring near the northwest end of the site. The 1991 study was a comprehensive regional study that does not need to be replicated. A copy of the 1991 study can be provided if needed.</p>

Reference Bibliography:

- Aley, Thomas. 1992. Final report: Groundwater tracing investigation, Arkwood Inc. Site, Omaha, Arkansas. Vol. 1. 103 p.
- Aley, Thomas. 1997. Groundwater tracing in the epikarst. IN: Proc. 6th Multidisciplinary Conference on Sinkholes and Hydrogeology of Karst Terranes. The Engineering Geology and Hydrogeology of Karst Terranes. A.A. Balkema, Rotterdam, pp. 207-211.
- Aley, Thomas. 2014. Revised final supplemental groundwater tracing study work plan, Arkwood Superfund Site, Omaha, Arkansas. Ozark Underground Laboratory contract report for McKesson Corporation, San Francisco, CA. 8 p. + attachments.
- Beeman, Shiloh L. and Thomas Aley. 2015. Groundwater tracing and recharge area delineation summary report, Cave Springs Cave, Cave Springs, Arkansas, Final Report. Summary report for the Cave Springs Area Karst Conservation Study, Cave Springs, Arkansas 62 p. + appendices.
- Benson, Richard C. and Lynn B. Yuhr. 2015. Site characterization in karst and pseudokarst terranes. Springer. Pp. 295-306.
- ERM-Southwest Inc. 1990. Remedial Investigation report, Arkwood, Inc. Site. Volume 1. 161 p. plus appendices.
- Hauwert, Nico M; James W. Sansom Jr.; David A. Johns; and Thomas J. Aley. 2004. "Groundwater tracing study of the Barton Springs segment of the Edwards Aquifer, Southern Travis and Northern Hays Counties, Texas." Barton Springs/Edwards Aquifer Conservation District and City of Austin Watershed Protection and Development Review Dept. Prepared in cooperation with the Texas Natural Resource Conservation Commission and U.S. Environmental Protection Agency. Approx. 250p.
- Smoot, J.L.; D.S. Mull; and T.D. Liebermann. 1987. "Quantitative dye tracing techniques for describing the solute transport characteristics of ground-water flow in karst terrane." Proc. 2nd. Multidisciplinary Conference on Sinkholes and the Environmental Impacts of Karst, Orlando, pp. 269-286.
- USEPA. 1990. Superfund Record of Decision: Arkwood, AR. U.S. Environmental Protection Agency Office of Emergency and Remedial Response. EPA/ROD/R06-90/064, September 1990. 88 p.
- Weight, Willis D. 2008. Hydrogeology field manual. McGraw Hill. Pp. 675-698.
- White, Keith A.; Thomas J. Aley; Michael K. Cobb; Ethan O. Weikel; and Shiloh L. Beeman. 2015. "Tracer studies conducted nearly two decades apart elucidate groundwater movement through a karst aquifer in the Frederick Valley of Maryland." National Cave and Karst Research Institute Symposium 5; Proc. of 14th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst, Rochester, MN. Pp. 101-112.